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W. H. M. CHRISTIE, M.A., F.R.S., President, in the Chair.

On the Photographs of the Corona at the Solar Eclipse of 1889, January 1. By Edward S. Holden, LL.D., Director of the Lick Observatory, Foreign Associate.

In the *Observatory* for March 1889, I have given a general account of the observations of the solar eclipse of January 1, 1889. I have also sent to the Royal Astronomical Society, in the name of the Lick Observatory, a positive copy on glass of one of the best negatives taken by Mr. Barnard of the Lick Observatory.

Since writing the letter in question I have been engaged in the preparation of a report on this eclipse, which will be printed by the University of California (of which the Lick Observatory is a part).

This report will contain the results of—

- (a) Observations at the Lick Observatory (of the partial phase);
- (b) Observations by the Lick Observatory field party at Bartlett Springs;
- (c) Observations by an eclipse expedition sent out by the Amateur Photographic Association of the Pacific Coast;
- (d) Observations by many other amateur observers.

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One section of this report is nearly completed, and I have thought that it might be of interest to communicate this section (which deals with the representation of the coronal forms as obtained from photographs and drawings) in advance of the printing of the whole report, which may require several months for its completion. I therefore beg to present two careful drawings which I have made, and a portion of the section of the final report.

The drawings are: fig. 1—which I have compiled from the various photographs taken by Mr. Barnard of the Lick Observatory with an ordinary Clark achromatic of 3 inches' aperture and 49 inches' focus (stopped down to $1\frac{3}{4}$ inch); and fig. 2, which is a copy of the outer coronal forms only, as they are shown on two negatives taken with portrait cameras by Messrs. Ireland and Lowden of the Amateur Photographic Association. The figures speak for themselves; the section of the report follows immediately.

“Diagrams of the Solar Corona from Photographs by E. E. Barnard of the Lick Observatory, and from Photographs by Messrs. Ireland and Lowden of the Amateur Photographic Association.”

“From the beautiful photographs of Mr. Barnard I have prepared the diagram or index map of the corona, which is given in fig. 1. One of Mr. Barnard's negatives was first copied in positive on glass, and a projection from this positive was thrown on a screen by a lantern. From this projection a careful drawing (Moon's diameter equal to $2\frac{5}{8}$ inches) was made. The positive was then examined by the transmitted light of a kerosene lamp through an opal glass shade under a magnifying glass, and the outlines obtained by projection were filled in. The parallel of declination, ecliptic, and vertex were then inserted from computations by Mr. Keeler. The Sun's axis is inclined $1^{\circ}24'$ to the north and south line as drawn.

“It is necessary to say that in making this diagram no pictorial effect has been sought for. It was intended to show only the more important features and details exhibited in the negatives obtained by the Lick Observatory party. The fainter details shown in the diagram are, necessarily, relatively too plain. A number of the minor features are omitted to avoid confusing the drawing, and because they were not well seen on account of the small size of the original negatives (Moon's diameter equal $\frac{4.6}{100}$ inches). The principal features are numbered for convenience of reference, from 1 to 113. Near the lines extending from the centre of the Sun towards the east and west, I have placed a scale of minutes of arc, corresponding to the faint circles described about the Moon's centre. The diagram is least satisfactory in the region 35 to 38.

“We may say *à priori* that the phenomenon of the Sun's corona

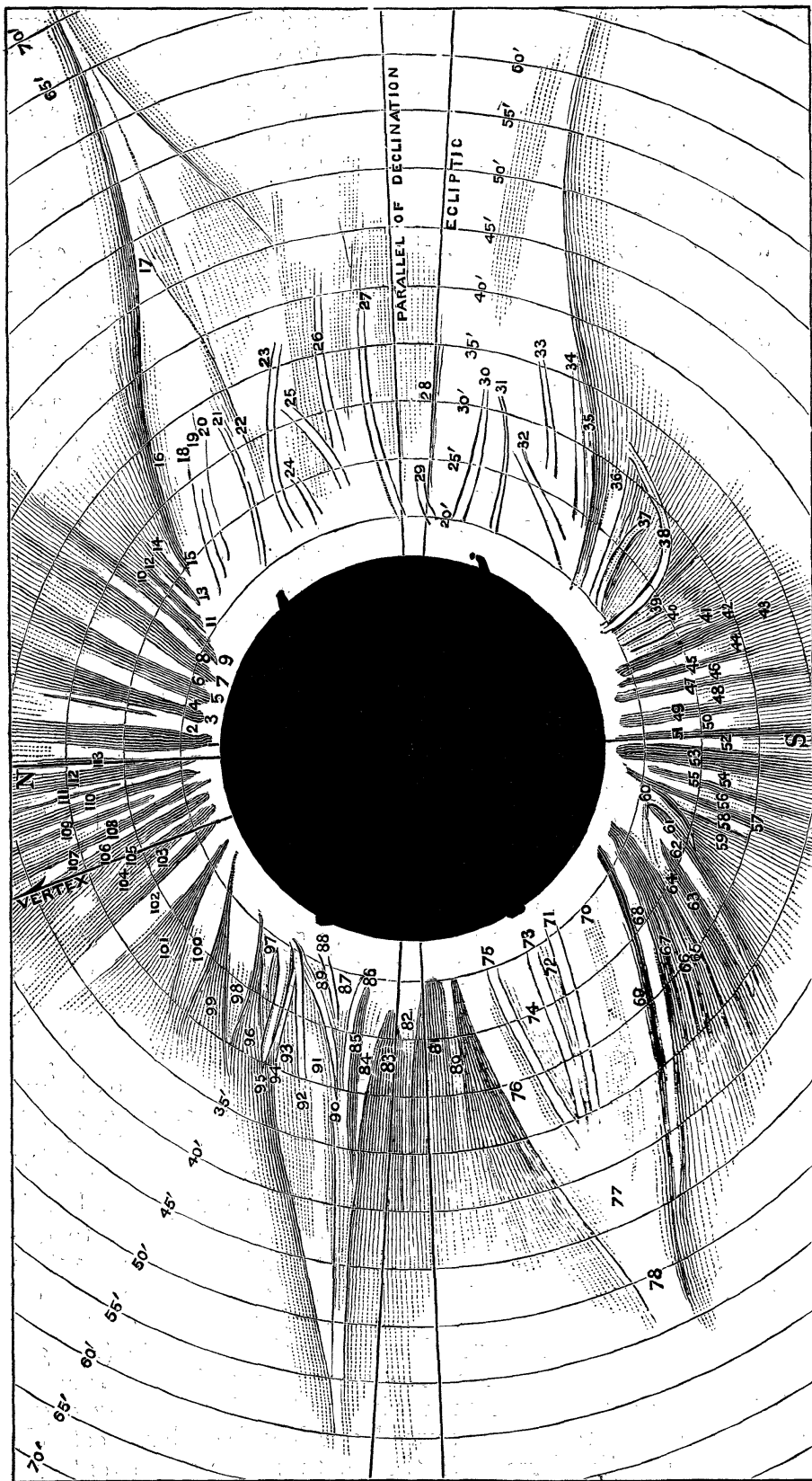


Fig. 1.—Diagram of the Solar Corona from photographs by E. E. Barnard, 1889, January 1.

is composed of at least three superposed appearances. There must be *first* some coronal effect due to diffraction &c. at the Moon's limb; *secondly* we have polar rays at the north and south poles of the Sun; and *thirdly* we have the equatorial wings or extensions. If we divide the phenomenon into parts by reference to brightness alone, and not simply as to structure, we have the inner corona (which is bright) and the outer corona (which is faint).

"Taking the corona as a whole, the first great result of the eclipse of 1889 is that *the characteristic coronal forms vary periodically as the Sun-spots (and the Auroras) vary in frequency.*

"Even a casual comparison of the drawings and photographs of 1889 with those of previous eclipses occurring at a period of minimum Sun-spots (the eclipse of 1867 and specially of 1878) shows that the characteristic forms of 1889 are typical of an epoch of minimum spots. The type for maximum spotted area is equally characteristic and very different. While there are minor features that vary from eclipse to eclipse, and do not seem to follow this law strictly, it appears that, broadly speaking, the eclipse of 1889 has established the correctness of the law above given, so far as our present data are sufficient. I believe that this law was first pointed out as probable by Mr. Ranyard (*Mem. R. A. S.*, vol. xli., 1879).

"We can best describe the parts of the corona as to extent and structure by reference to the index-map. The map shows the outer coronal wing at the south-east, extending as far as 78, or 55' from the Moon's centre. At the north-west it extends fairly bright to 17, or 50', and it can be traced to the 75' circle by looking obliquely at the negatives, or by slowly moving them before a bright lamp with a porcelain shade. The south-west wing extends to the 50' circle as fairly bright, and can be traced to 60'. The north-east wing, or ray, can be traced to 55'. All the important polar rays extend as much as 25' to 30' from the Moon's centre, and the longest ray (2) attains a length of 36' in Mr. Barnard's best negative. There is little detail (except the four hydrogen flames) to be seen between the Moon's limb and the 20' circle. It will be noticed that the south-west protuberance is in two distinct parts. A few of the narrow dark polar rifts (1, 3, 5, 7, 9, 43, 45, 47, 49, 51, 53, 57, 67, 69, 99, 101, 102, 103) end within the 20' circle. The bright ring immediately around the Moon's limb may be in a small degree due to the chromosphere, but it seems likely that a certain portion of it, at least, is due to diffraction. The inner corona ceases to be bright at about 25' in general, and in the wings 17, 30, 77, 92, the brightness falls off rapidly beyond the 30' circle. A very curious feature of the best photographs is, that the coronal wings on the west side (20, 30) seem to have their north and south edges (16, 34) roughly parallel as far out as 45' or 50'; while at this distance the edges (16, 17, 34) begin to diverge towards north and south respectively into a trumpet-like form. If the photographs are attentively

considered, they appear to show that the coronal beams inside the 50' circle are gradually concentrating themselves. This seems to be their law as far as this point. It is therefore surprising to find at the 50' circle the strongly marked tendency to divergent forms and to a trumpet-shaped extension. If the negatives did not show any portion of the wings beyond 45' or 50', it would be at once concluded from them that these extensions were convergent. But from the 50' circle outward to 65' and 75' (on the west side of the Sun) the lines (16, 17, and 34) become strongly divergent, so that at the 65' circle their distance apart (north and south) is already something like 45'.

"When I first discovered this in Mr. Barnard's negatives, I was inclined to doubt the position of the faint edges (16, 17, and 34), which I had laid down from the photographs, and I therefore sought for some evidence from the many drawings which had been sent to the Observatory for discussion.

"The drawings of Miss Robertson at Cloverdale, Mr. Staples at Bartlett Springs, Miss Silvia Rey at Cloverdale, Miss Nellie Treat at Cloverdale, Mr. C. Mason Kinne at Cloverdale, clearly indicate something of the trumpet-like extension referred to on the west side of the corona. In particular the sketch of Miss Treat shows an extension of the south edge of the south-west wing extending to 89' from the Moon's centre. These drawings were all made without hiding the inner corona from the eye. The drawing of Miss Treat in particular agreed beautifully in direction with the line (34) of the photographs. The divergent character of the coronal wings on the west side of the Sun is completely proved by the photographs and by the drawings referred to, and the line (35, 34) can be drawn as far as 65' with no doubt whatever, and with considerable confidence as far as 89' from these two authorities alone. Fortunately for the question, the Observatory possesses a large number of photographs made by the members of the Amateur Photographic Association (see the reports in Part III.). A large number of these yield important evidence on the question of the extension of the outer corona, especially those of Messrs. Lowden, Ireland, Dornin, Treat, Passavant, Grimwood, and Burckhalter. Two of them, however, made by Mr. Lowden and by Mr. Ireland respectively, are so remarkable and so conclusive that we need only consider these two in order to obtain an entirely satisfactory portrayal of the outer coronal beams. It must be remembered that no previous photograph of the corona has extended beyond 50' from the Sun's centre, so far as I know, and we are now concerned only with the description of the corona beyond the circle of 65 minutes. As I have said, the photographs of Mr. Barnard, together with the drawing of Miss Treat, carry the outlines of the outer corona out beyond the 80' circle. The photographs of Mr. Ireland and Mr. Lowden are naturally wanting in detail near the Sun, but beyond the 60' circle they seem to carry the outlines of the four coronal wings as far as 135' and 165' respectively.

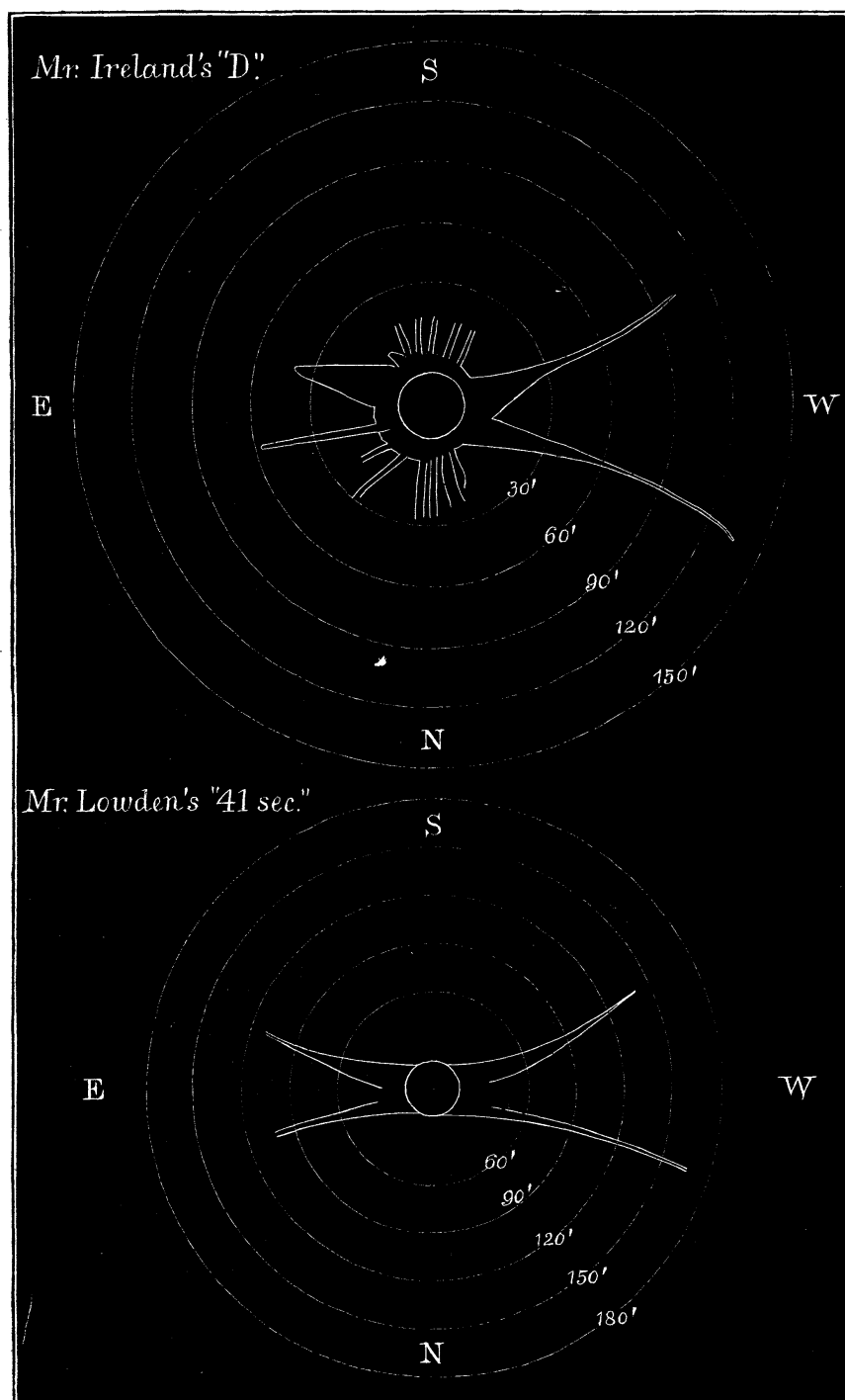


Fig. 2.—Diagrams of the Outer Corona, 1889, Jan. 1, from photographs by Messrs. Ireland and Lowden.

“The shortest way to present the evidence of these pictures is to copy their main outlines, which I have done in fig. 2. The scale is different for the two figures, but the circles concentric with the Moon's centre will serve as means of comparison. The

copies have been made from positives (and are reversed north and south from the index-map of Mr. Barnard's pictures, as all measurements with the compasses had to be made on the glass, and not the film-side). A very summary examination of the pictures will show plainly that the wings *certainly* extend as follows:

				Ireland	Lowden.
The north edge of the N.W. wing	...	...	...	96'	83'
The south edge of the S.W. wing	...	...	...	94'	79'
The axis of the S.E. wing	...	...	...	69'	69'
The axis of N.E. ray or wing	...	...	...	79'	76'

Mr. Lowden's second plate (21 secs.) gives these distances, to which the wings are obvious, as 89', 69', 66', 85' respectively.

"If the pictures are held obliquely in a strong soft light, or moved gently in front of such a light, these limits are very much extended, and I am satisfied that the drawings in fig. 2 would be verified by anyone who will give the requisite attention. The appearance of the planet *Mercury* on Mr. Lowden's plates shows that the camera (which was kept pointed by hand by means of a finding telescope) did not follow the Sun exactly. In spite of this fact the extension of the outer corona is extremely great, as we have seen. If this camera had been accurately driven by clockwork we should have had even more detail and extent than they now show, remarkable as this is. It should be said that Mr. Ireland's 'D' shows the detail of the polar rays and of the inner corona much better than the others (where these were lost by imperfect driving of the camera during the long exposures), and it accordingly seems that Mr. Ireland's experiments as to light, exposure, plates &c. should be repeated at some future eclipse. It thus appears that the new feature of the corona which just begins to show plainly in the photographs by Mr. Barnard, and in the drawing of Miss Treat, is very satisfactorily portrayed in the negatives taken by Messrs. Lowden and Ireland at different places and with different instruments. Many other negatives by members of the Pacific Coast Amateur Photographic Association lend independent corroboration to the conclusion already drawn. I may also cite a beautiful negative by the Rev. Father Charroppin, which extends nearly as far, is full of detail, and entirely confirms the existence of the trumpet-shaped extension of the outer corona. It is worthy of note that the drawings of the outer corona by Professors Newcomb and Langley at the solar eclipse of 1878, which show the outer corona extending several degrees on each side of the Sun, present no evidence of the branching forms shown in the negatives just described.

"There is no connection proved by this drawing between the prominences and the streamers, and a direct connection of this kind is probably *à priori* unlikely. It must, however, be said that the four chief prominences visible are at or very near the bases of characteristic coronal forms as they appear in the drawing.

"There are a few constantly recurring types of coronal structure. The polar rays exhibit the most pronounced type, perhaps. At the North Pole the bright rays (98, 100, 102, 103, the lower part of 105, 108, 110, 111, 113; 2, 4, 6, the lower part of 8, &c.) are essentially of one type. They extend nearly radially near the poles with a tendency to be convex towards the Sun's axis prolonged to the north. 105 is curved and convex to the axis, while 8 is strongly concave in all of Mr. Barnard's negatives. (This is quite different in the Harvard College positive, which has been kindly presented to the Lick Observatory by Mr. W. H. Pickering. I have drawn Prof. Pickering's attention to this difference, and a careful examination of the negatives of the Harvard College and the Lick Observatories will be made to decide whether in fact one of the coronal forms changed its shape between the instants corresponding to our respective negatives.)

"Many of the bright polar rays are doubled, as 109, 111, 113, 2, &c. The doubling in many cases does not appear to be due to a perspective projection of one ray upon another, but, so far as mere looks are concerned, the duplicity appears to be structural. We must of course imagine the whole area of the Sun's surface near the poles to be bristling with a network of these radial beams, whose analogy to the Auroral beams on the Earth is most marked. At the south pole of the Sun the same type occurs in 68, 67, 64, 62, 58, 56, 54, 52, 50, 48, 46, 44, 42, 41, 40, 39, 38, 37 (which has contrary curvature), 36, 35, &c. The centre of radiation of each set does not appear to be at the Sun's centre. The dark rifts between the bright rays are usually fairly straight in general direction. Their sides are not rectilinear, however, when attentively examined, and their roots are singularly terminated (notably in the case of 1). The bright polar rays projected near the south pole are in general straighter than those at the north (which was turned away from the Earth on January 1).

"I have said, in what precedes, that we must conceive the whole surface of the Sun near the two poles to be bristling with these Auroral (?) streamers, and this is the usual view of the matter. I see no reason, however, for supposing that such rays are confined to regions near the two poles. On the other hand the rays, 23, 24, 25, 26, 27, 28, 29, 30, 31, 32, 33, 34, 35, on the west side of the Sun, and 80, 82, 94, 95, 97, 98 on the east side, appear to me to be of the same general nature as the bright polar rays. They are nearly always curved (though 80 and 82 are marked exceptions), and in general they are curved towards the Sun's equator. If we examine the lines of force at the poles of a bar-magnet there is no discontinuity between the families of rays at the ends of the magnet and those at the sides; and in the case of the Sun also, the so-called 'polar' rays appear to extend all around the disc. There is no latitude at which we can say that here the polar rays end, and a new species—equatorial rays

—begins. For example, 58 is a polar ray; so is 64; so, it seems to me, is 80 in all but situation. Again, what is to distinguish 6, 8, 10, 12, 14 (which are all of the polar type), from 23, 25, 26, except their curvature and their situation?

“The equatorial rays are all projected, it must be remembered, on a bright background, which does not exist at the poles. If this background were removed, we should, I think, at once see that the typical polar rays do in fact extend all round the disc, being least plentiful at the solar equator. I would therefore consider that the first characteristic type of structure consists of rays ordinarily called ‘polar,’ which are not connected with any bright background, and of such others (as 80 and 82 for example) as have no connection with the wing-like extensions.

“It is clear that there is a second type of rays which are connected with the wing-like forms. The best examples of these are 71, 73, 75, 84, 86, 88, 90, and probably 18, 19, 20, 21. These give the peculiar striations to the wings. A very interesting recurrence of a type is shown in the cases of 23, 24, 25; 36, 37, 38, and 86, 88, 90, and perhaps at 60, 61, 62. The symmetric arrangements of these groups is noteworthy. It is interesting also to observe that the two darkest and narrow polar rifts are nearly opposite to each other. I have found no cases of curved rays which bend completely over as in Mr. Wesley’s diagram of the eclipse of 1871 (*Monthly Notices R.A.S.*, vol. xlvii. p. 501).

“As is well known, the solar spots occur chiefly in two zones extending from 5 to 40 degrees of solar latitude, north and south. A few spots occur near the solar equator, none beyond 45 degrees of latitude. Carrington’s observations (1853–1861) show the greatest number of spots to be in latitudes 20° N. and S. Spoerer’s observations (1861–1867) show the greatest numbers in latitudes 10° N. and S. The wings of the corona of 1889 have their axes about as follows, if we suppose them to lie in the plane perpendicular to the line of sight:

N W. wing, axis in latitude	48° N.
S.W. „ „	14 S.
S.E. „ „	28 S.
N.E. „ „	20 N.

“It is possible that the connection of such wing-like extensions with the zones of maximum spots has been too hastily assumed. . . .”

The Trapezium of Orion. By S. W. Burnham, M.A.

Perhaps no object in the sidereal heavens has received more attention from astronomers than the multiple star θ *Orionis*. It has been the subject of careful study by the most eminent observers, provided with the best astronomical instruments; and the relative positions of the principal stars have been determined with the greatest possible accuracy. Certainly no equal area in any other part of the sky has furnished room for the location of so many purely imaginary stars. At intervals during the last fifty years various observers have recorded a number of stars in the space enclosed by the four bright stars of the trapezium. As a rule these alleged discoveries have been made with small telescopes, even down to four inches' aperture, and by observers with little or no experience in double-star work. As would be expected, perhaps, in an object as carefully studied as this has been for the last twenty or thirty years, all the large and most perfect modern refractors, directed by the most experienced double-star observers, have utterly failed to show, under the best atmospheric conditions, the least trace of a single one of the dozen or more supposed new stars. The great 26-inch at Washington, until recently the most powerful telescope in the world, revealed nothing to Hall in the course of a long series of measures of the known stars of this group. The other large telescopes in this country—the McCormick 26-inch, the Princeton 23-inch, the Chicago 18½-inch, the Madison 16-inch, and the Harvard 15½-inch—were equally unsuccessful.

The trapezium was carefully examined by me with the Chicago telescope, at times under very favourable circumstances, and as the result of the search for the new stars (*Mem. R.A.S.* vol. xlv. p. 99) I stated:—

“Several observers have seen, or believe they have seen, minute stars in the trapezium. . . . While making the measures given above, and at other times, under very favourable conditions, the interior of the trapezium and the vicinity of the principal stars were carefully examined. There was not the slightest suspicion of any additional stars. If the sixth star itself had been double, with a distance of 1'', it could not have been overlooked. I have very little faith in the real existence of these suspected stars after the failure of this and other large refractors to show them. It is wholly improbable that they should be variable in such a manner as to render them at all times invisible within the last few years. In regard to the alleged variability of the fifth and sixth stars, I can only say that they have always been readily seen with my 6-inch in the last six years when the atmospheric conditions were suitable. So far as my observations go there appears to be no evidence of change in the light of these stars.”